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# Aquatic Plant Control Research Program

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# Ecological theory and the management of submersed aquatic plant communities

*by*
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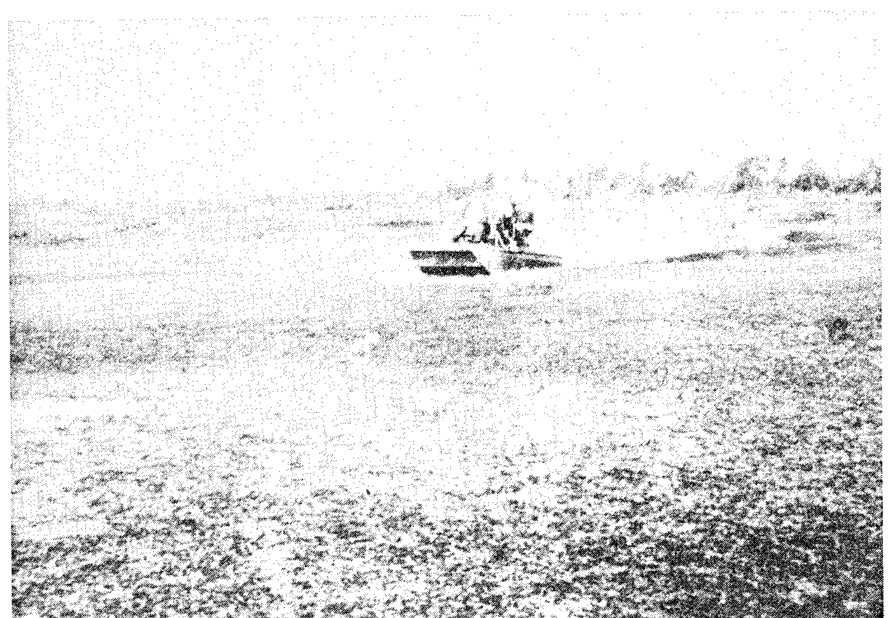
The control of aquatic plant problems historically has been driven by short-term and very localized goals—immediate solutions for critical problems. However, in focusing on providing rapid solutions to specific problems, aquatic plant managers have often ignored longer term and system-wide management objectives. This "crisis management" approach—providing short-term, localized solutions to long-term or recurring problems—is unlikely to result in the most effective, system-wide management of aquatic resources. A holistic approach to aquatic plant management is needed.



**Basic ecological principles can help aquatic plant managers avoid problem growths of submersed aquatic plants, such as this monoculture of hydrilla**

This article describes the development of innovative aquatic plant management strategies based on well-established principles of ecological succession. Population- and community-based concepts borrowed from the body of basic ecological theory can help managers avoid extensive monocultures of problematic species, such as that shown in the photo below.

The narrow perspective of most aquatic plant management plans results both from agency funding constraints and from an inadequate understanding of the ecological functioning of large, multipurpose reservoir ecosystems. Fortunately, there is a considerable body of basic ecological theory that appears pertinent to the management of aquatic plants.

This article considers the management of submersed aquatic plant communities in Corps of Engineers reservoirs and waterways in relation to basic ecological precepts. These concepts form the basis of a management approach that promotes ecological sustainability while achieving long-term and system-wide management objectives for multiuse aquatic resources.

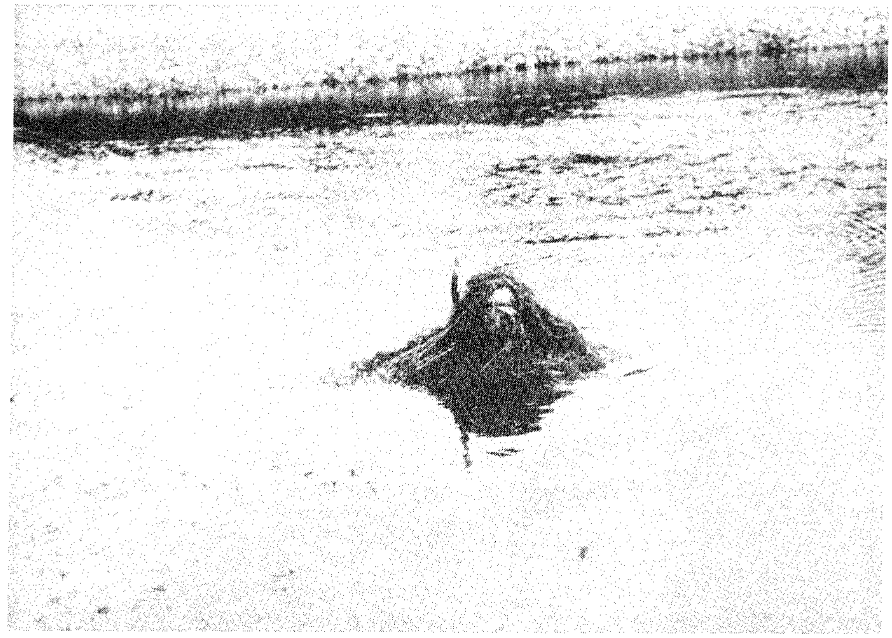
# Dr. Jekyll or Mr. Hydrilla?

While some species of submersed aquatic plants cause serious management problems, most species contribute significantly to the aquatic environment by stabilizing the sediments, removing excess nutrients from the water, improving water clarity, and providing quality habitat for fish, waterfowl, and other organisms. Beneficial submersed aquatic plant communities typically have low to moderate levels of biomass production, include a high diversity of species which provide structurally diverse habitats, and are dominated by growth forms that concentrate biomass below the surface of the water (Figure 1). These communities provide both desirable aquatic habitat and water quality benefits. Light, temperature, pH, and oxygen distribution within these communities are favorable throughout the diurnal cycle.

While a diverse native aquatic plant community is a desirable feature of the aquatic ecosystem, excessive growths of submersed aquatic plants can cause serious and costly management problems and interfere with continued use of the water resource for project objectives. Problems typically occur when extensive populations develop *very high levels of biomass* and have a growth form that produces *a dense canopy of vegetation at the air-water interface* (Figure 1).

When such populations grow in strategic or high-use locations, such as boat ramps, channels, water intakes, or swimming areas, an immediate management problem results. Under these conditions, the beneficial aspects of having plants in the aquatic environment are outweighed by numerous management problems.

When surface canopy-forming plants occupy a large proportion of the shallow-water environment,



**Depending on their biological characteristics, aquatic plants can be either good or bad for the environment**

they not only interfere with the use of the water resource, but also create ecological and water quality problems.

Ecological problems develop when surface mats prevent the penetration of light into the water, thereby restricting photosynthesis to a shallow zone near the water surface and effectively obstructing the growth of other plant species. This may lead to extensive monospecific plant populations and a poor-quality habitat that favors a limited number of organisms, further contributing to low biodiversity. Water quality problems develop because the mat physically impedes gas exchange between the air and water, minimizes wind-generated mixing, and obstructs water circulation. These surface mat characteristics (high biomass, poor light penetration, and limited mixing) combine to create very poor water quality and habitat conditions. During seasonal periods of senescence and decay, extensive beds of dense vegetation can cause widespread oxygen depletion (and associated fish kills), interfere with the functioning of water intakes, and contribute to massive algal blooms, as limiting nutrients such as phosphorus are released to the water.

However, not all submersed aquatic plants cause these problems. In fact, of the approximately 1,300 species of aquatic plants (submersed, emergent, and floating) found in North America, only a very few *ever* cause serious, widespread problems. Most of the severe aquatic plant problems in reservoirs are caused by a few weedy exotic species (those introduced from other countries and not native to North America). Are these exotic species more competitive than our native species? No! But these species have evolved numerous biological characteristics that make them highly adapted to the environmental conditions typical of reservoirs.

In nontechnical terms, these *problem species* are considered "weeds." *Webster's Third New International Dictionary* (1986, unabridged) defines a weed as "1. an economically useless plant of unsightly appearance and of wild or rank growth; 2. ***a marine or freshwater plant.***"

These definitions not only highlight the undesirable nature of such plants, but reveal a lot about the perspective from which *all* aquatic plants have often been considered. However, in ecological terms, these problem plants are more appropriately considered "ruderal" species. Ruderal is defined as "pertaining to or inhabiting disturbed sites" (Ricklefs 1990). The latter term more accurately describes the nuisance species with which aquatic plant managers and scientists are concerned. The use of this term in an ecological context also provides access to a considerable body of basic ecological information on factors governing both the distribution of species and the species composition of plant communities.

## Ecosystem succession

It has long been recognized that, in an ecosystem suffering a major disturbance, populations (animal or plant) appear to replace each other in predictable and orderly stages during ensuing stable periods. This process, referred to as ecosystem succession, is begun by a colonization period during which a few scattered, but rapidly growing, ruderal or pioneer species become established. These species, well adapted to disturbed conditions, reach a high reproductive capacity early in the life cycle, quickly disperse throughout the environment, and soon achieve dominance. They are able to tolerate a wide range of environmental conditions and recover quickly from periodic disturbances. In the absence of disturbance, the environment becomes more stable, populations approach the carrying capacity of the environment, and other growth strategies become more effective.

Pioneer species developing in fertile environments, by their own demands, reduce the availability of environmental resources. This process selects for competitive species, which are able to capture and retain these limiting resources. Over time, ruderal species are slowly replaced by higher successional, competitive species that have longer life spans and produce fewer, more competitive offspring. This process culminates with the establishment of a diverse, *stable climax community* of competitive, long-lived species.

The creation of a reservoir is easily recognized as a major disturbance. Accordingly, the first species to colonize this recently

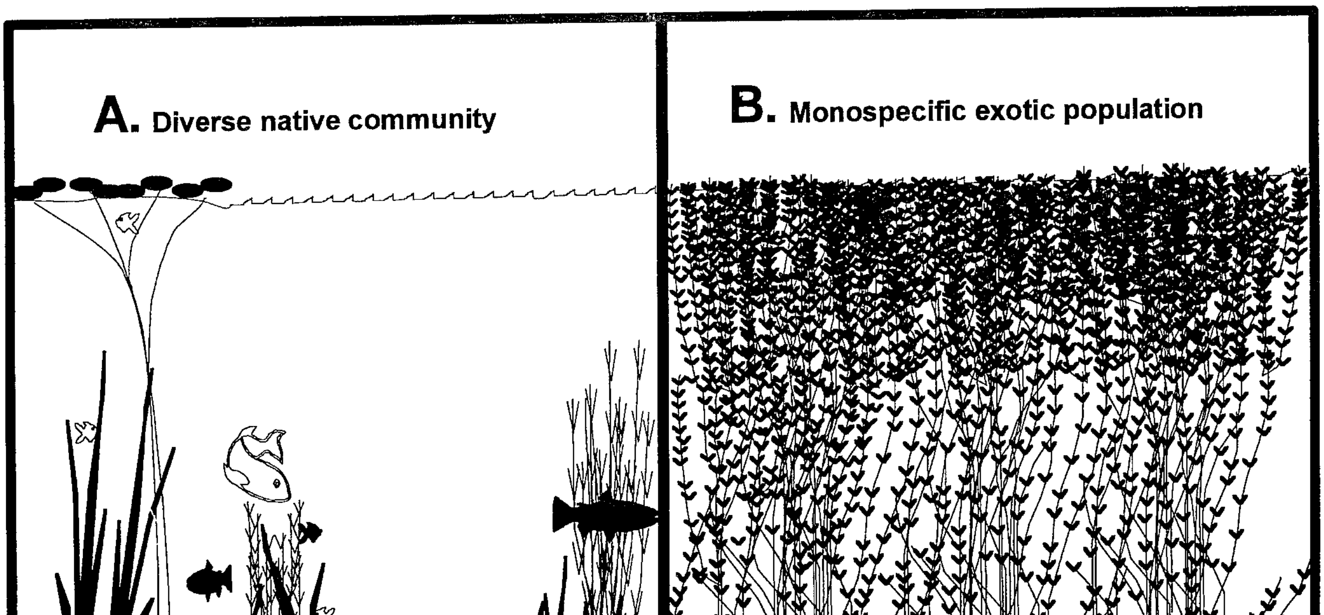



**Figure 1. Diverse native aquatic plant communities (panel A) provide desirable habitat and contribute to good water quality. In contrast, monospecific populations of nuisance exotics (panel B) form dense surface mats, minimize the structural diversity of the environment, and often degrade water quality**

disturbed site are expected to be pioneer species. Many of the native pioneer species are annuals that complete their entire life cycle in one growing season, culminating with the production of copious numbers of seed. These pioneer species modify both the sediments and the water column of the newly formed reservoir in important ways. The pioneer species promote stability and actually provide conditions favorable for growth of higher successional species. These pioneer species are generalists, highly adapted for rapid colonization of disturbed areas, but they are fairly easily replaced in the successional sequence by longer lived, perennial species. However, the seeds of the pioneer species remain dormant in the sediment seedbank. This seedbank provides a means for quick recovery of the vegetation if a subsequent disturbance sets the community back to an earlier successional state. In short, stability favors competitive species, while disturbance (by eliminating competitive species) sets back the clock, favoring pioneer species.

While "climax" aquatic plant communities that consist of competitive species will naturally and eventually replace pioneer species, this replacement requires that stable conditions (the absence of disturbance) prevail for an extended period of time. While the exact time course of succession in a particular environment is determined by the life histories of the principal organisms living in the environment, it is generally slow. In terrestrial environments the process is usually measured in decades or even centuries!

## Biological characteristics of nuisance aquatic plants

As discussed above, in contrast to Webster's second definition of weed, not all aquatic plants are weeds requiring management attention. Most native aquatic plants are desirable, providing many environmental benefits. However, several exotic or introduced aquatic plant species truly deserve to be called noxious *weeds* in every sense of the word. Among submersed aquatic plants, managers are primarily concerned with the exotics hydrilla (*Hydrilla verticillata*) and Eurasian watermilfoil (*Myriophyllum spicatum*). The prolific growth of these two plant species requires that managers promptly apply aggressive, systemwide management practices to ensure that the benefits provided by a diverse native aquatic plant community are not lost. Hydrilla and Eurasian watermilfoil cause environmental and water quality problems because they exhibit particular biological characteristics, discussed below.

- **Ecological growth strategy.** Both hydrilla and Eurasian watermilfoil possess many "weedy" adaptations that allow them to exploit environments with frequent disturbances. Among the most problematic of such characteristics are rapid growth rates, high reproductive capacity, and rapid dispersal. These traits contribute to the explosive spread of these species in reservoirs lacking well-developed aquatic vegetation.
- **Morphology.** These plants elongate and rapidly grow to the surface for light, where they develop highly branched canopies at the water surface. These surface mats allow the plants to maximize capture of sunlight, but interfere with usage of the water resources and cause degraded water quality and habitat conditions.
- **Environmental tolerance.** Both hydrilla and Eurasian watermilfoil tolerate a wide range of environmental conditions and thrive even in turbid or eutrophic systems.
- **Origin.** The adverse effects of introduced species, though difficult to predict, are more the result of their biological characteristics than their being foreign. However, introduced species may have fewer restraints on their growth potential because of the absence of natural control agents (pathogens, insects, vertebrate herbivores, or competitors) in the new environment. Both hydrilla and Eurasian watermilfoil are exotic species and are unwelcome additions to U.S. waters.

These characteristics allow problem species to very quickly exploit and monopolize new sites (reservoirs), and once established, these plants quickly cause water resource problems that require management action.

Hydrilla and Eurasian watermilfoil are unusual in that they have characteristics of both ruderal species and competitive species. Like most weeds, these plants are adapted for disturbed environments and have a very high dispersal potential. However, unlike typical ruderal species which reproduce only vegetatively or by seed and rely on the absence of competitors in the environment, hydrilla and Eurasian watermilfoil have some competitive characteristics as well. Foremost among these in hydrilla is the formation of tubers. These tubers are much larger than the seed of most submersed aquatic plant species and contain considerable stores of carbohydrates, allowing for rapid and vigorous regrowth each spring or after a disturbance

to the environment. Eurasian watermilfoil develops massive root crowns to which it diverts and stores carbohydrates over the winter. Consequently, once established, these plants are quite competitive, and it is difficult for higher successional species to outcompete them. While these species are ideally adapted for disturbed systems, they are not typical ruderal species because there appears to be no opportunity for higher successional species to displace them. This ecological growth strategy may need a new name such as *preemptive*. That is, they get there first, dominate, and don't let go!

## Aquatic plant problems in Corps reservoirs

Why are submersed aquatic plant problems so widespread in Corps reservoirs? When viewed in light of the ecological principles described above, the answer becomes clear. It appears that at least four fundamental factors have combined to create a situation in which aquatic weeds can flourish and the potential for aquatic plant management problems is maximized.

First, Corps reservoirs and waterways are not natural systems. Where natural lakes have developed over hundreds or thousands of years, reservoirs are flooded and formed within a few months. Reservoirs are very young in an ecological sense and have large expanses of potential aquatic plant habitat, but often have very limited or no populations of aquatic plants to provide sources of propagules for vegetating these broad areas. In the absence of appropriate native species, it is not surprising that exotic weedy species, which can spread very rapidly, flourish.

In addition, since reservoirs are created by impounding flowing water systems, we often have a chain of reservoirs "linked" by the river flowing through them. Unlike natural lake systems, these reservoir systems have a much more variable hydrology, lack buffer wetlands in the headwaters and around the margins, and have a large ratio of shoreline to water volume. Each of these contributes to the potential for weed problems.

Second, most reservoirs are eutrophic systems with relatively high nutrient inputs. The eutrophic conditions provided by past and current nutrient loading rates have likely contributed greatly to our aquatic plant problems by promoting the growth of surface mat-forming species.

Third, project operations and natural disturbances promote the continued dominance of weedy species. Any type of disturbance (whether natural or directed by man) that serves to remove the existing vegetation cover sets the system back to an earlier successional state, and thereby promotes the spread of ruderal or weedy species. Such disturbances might include

- Extreme or prolonged water-level changes (high water levels due to flood storage, low water levels due to drought or intentional drawdowns).
- Extreme weather conditions such as hurricanes.
- Short-term salinity fluctuations in coastal areas.
- High-flow conditions on main stem river reservoirs.
- Prolonged high turbidity levels or high nutrient concentrations.
- Extreme winter conditions and associated ice damage.
- Large-scale or extreme overgrazing (waterfowl "eat-outs," grass carp).
- Construction and dredging operations.

Finally, and perhaps most surprisingly, when viewed from an ecological perspective, our past management practices may have exacerbated problems with exotic, weedy species. Although driven by the need to control the excessive growth of exotic species, historical management approaches often considered all submersed aquatic plants to be *weeds* and the goal of management, to eradicate all submersed vegetation (Gallagher and Haller 1990). Thus, in our attempts to eliminate weeds, much desirable vegetation was also destroyed. Management actions to control nuisance growths actually promoted the spread of weedy species by keeping the system in an artificially high state of disturbance.

## Ecologically based approach

Based on the ecological principles outlined, suggestions can be made regarding general management strategies for reservoirs. These ideas are intended as fundamental principles that should be considered in developing specific management plans for individual reservoirs. While in many cases the research has yet to be done to make the implementation of these concepts fully operational, an understanding of the principles involved can provide resource managers with an ecological perspective that will foster a longer term, holistic approach to ecologically sustainable aquatic plant management.

A key to making ecological succession work in our favor will be to minimize disturbances to the reservoir. We recognize that many types of disturbance are beyond our control and that other disturbances are necessary for achieving project objectives (such as flood control). However, the potential impacts of project operations on the aquatic plant community should be considered.

## Accelerated succession: management for systems without exotics

The task of managing the aquatic plant community within a reservoir is greatly simplified if nuisance exotics have not yet invaded the lake. The manager's goal should be to ensure the presence of a diverse native plant community.

If little or no vegetation is present in the reservoir, the first step will be to establish native pioneer species. While pioneer species would eventually find their way to an unvegetated reservoir, the rapid spread of exotic species dictates that we intervene and accelerate the process. Otherwise, exotic pioneer species are likely to arrive first. Once pioneer species become widely distributed, they will change the aquatic environment by consolidating the sediments, clearing the water, and reducing nutrient concentrations, thus preparing the reservoir for more desirable, higher successional plant species. These native pioneer species will also provide much-needed aquatic habitat and should present few management problems. In addition, during later stages of successional development, remnant populations of these species and a viable seedbank will ensure rapid recovery following necessary or unavoidable disturbances to the reservoir ecosystem.

In systems that are not frequently disturbed by management action, the effort to establish pioneer natives should later be supplemented by plantings of higher successional native species such as wild celery (*Vallisneria americana*). The effort involved in accelerating the successional process by establishing native pioneers will provide immediate habitat and water quality benefits, contribute to the establishment of higher successional species, and ensure that an appropriate mix of both ruderal and competitive species occurs in the lake, minimizing the chance of widespread infestation by nuisance exotic species.

This concept of stocking desirable organisms to manipulate the composition of lake communities is not new. Fisheries managers have for decades stocked desirable fish into reservoirs. Often, surveys of fish communities are performed annually, and additional stockings are undertaken to achieve the desired fish community. This concept needs to be extended to the management of aquatic plant communities.

## Ecological restoration: management for systems with exotics

Left to nature, successional changes from exotic pioneer species to more desirable, competitive species will occur slowly, or in the case of hydrilla, perhaps not at all. Therefore, if we are to enjoy the benefits of diverse native plant communities in these infested lakes, we need to intervene and restore an ecological balance. To reclaim these infested reservoirs, managers must take prompt, aggressive, system-wide action to displace the nuisance plants and replace them with more useful species. Successful restoration will likely require integration of all available aquatic plant management tools, including chemical control, biological control, mechanical control, and drawdowns, with an *ecologically based plant competition strategy.*

Herbicide treatment will be necessary in most cases to eliminate problem species from certain locations so that they can be replaced with appropriate natives. However, merely treating the problem species without establishing beneficial native plants is simply too shortsighted to continue. Follow-up treatments will require species-selective control methods to reduce the growth of exotic species while not seriously damaging the newly established native plant community. Innovative application techniques that incorporate recent advances in herbicide technology may soon allow us to control some nuisance species while not harming many of the beneficial natives.

Another important combination of management methods will be the integration of biological control along with plantings of appropriate native species. Typically, biological control treatments do not completely eradicate nuisance plants, but simply impact the population's growth potential. Successful biological control thus depends on the presence of competing species in the environment in order to displace the nuisance target. If appropriate native species are not present in the environment, reservoir managers will need to introduce them.

## Conclusion

Attention to basic ecological principles will provide managers with the opportunity to develop ecologically sustainable, system-wide objectives for multiuse water resources. Much research remains to be done. However, immediate and significant improvements in our management of water resources can be achieved by understanding the process of ecosystem succession, the fundamental ecological differences between desirable native plants and exotic weeds, and the need to view the aquatic plant community in the same management light in which we have long viewed the fish community.

## References

Gallagher, J. E., and Haller, W. T. 1990. "History and development of aquatic weed control in the United States," *Reviews of Weed Science,* Vol 5, pp 115-192.

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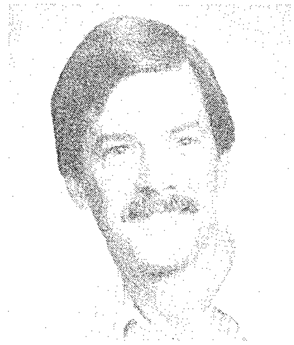

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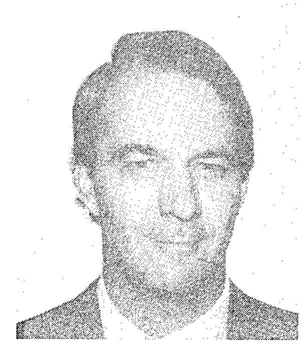

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# Calendar of events

| | |
|---|---|
| July 9-12, 1995 | **Aquatic Plant Management Society, Inc.**, 35th Annual Meeting, Hyatt Regency Hotel, Bellevue, WA, POC: Steve de Kozlowski, (803) 737-0800 |
| August 16-18, 1995 | **South Carolina Aquatic Plant Management Society**, 17th Annual Meeting, Springmaid Beach Recreation and Conference Center, Myrtle Beach, South Carolina, POC: Larry McCord, (803) 761-8000 |
| October 17-19, 1995 | **Florida Aquatic Plant Management Society**, 19th Annual Meeting, St. Petersburg Hilton, St. Petersburg, FL, POC: Nancy Allen, (904) 795-2239 |
| October 18-20, 1995 | **MidSouth Aquatic Plant Management Society**, 14th Annual Meeting, Ramada Shoals Hotel and Conference Center, Sheffield, AL, POC: Scott Lankford, (205) 664-6039 |

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*This issue describes innovative aquatic plant management strategies based on concepts borrowed from basic ecological theory. This approach promotes ecological sustainability and helps aquatic plant managers achieve long-term, system-wide objectives, rather than focusing on short-term, localized solutions.*

## AQUATIC PLANT CONTROL RESEARCH PROGRAM

This bulletin is published in accordance with AR 25-30 as one of the information dissemination functions of the Environmental Laboratory of the Waterways Experiment Station. It is principally intended to be a forum whereby information pertaining to and resulting from the Corps of Engineers' nationwide Aquatic Plant Control Research Program (APCRP) can be rapidly and widely disseminated to Corps District and Division offices and other Federal and State agencies, universities, research institutes, corporations, and individuals. Contributions are solicited, but should be relevant to the management of aquatic plants, providing tools and techniques for the control of problem aquatic plant infestations in the Nation's waterways. These management methods must be effective, economical, and environmentally compatible. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such products. This bulletin will be issued on an irregular basis as dictated by the quantity and importance of information to be disseminated. Communications are welcomed and should be addressed to the Environmental Laboratory, ATTN: J. L. Decell, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call (601) 634-3494.

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